PREDICTING CROP RESIDUE IN CROPPING SYSTEMS

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Abstract

A prototype of decision support system entitled Residue Recommendation System (RESREC) has been developed to predict changes of crop residue with time in cropping systems typical of Western Canada. The system uses the Douglas/Rickman model to simulate decomposition, and tillage coefficients to calculate the effects of field operations on residue levels. Decomposition is simulated by calculating the loss based on an empirical relationship to long-term means for air temperature, the nitrogen content of the crop residue, and placement of the residue. Overall, the nitrogen content was correlated with decomposition rates of spring wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), canola (*Brassica napus* L.), and flax (*Linum usitatissimum* L.) straw and alfalfa (*Medicago sativa* L.) hay. Overwinter loss of crop residue varied considerably between crops and further research is required to quantify these rates.

INTRODUCTION

Residue managment is a primary concern of producers who direct seed annual crops in the Parkland. Surface-placed residues affect emergence, germination, soil cover, nutrient availability, soil structure, soil temperature, water infiltration and evaporation, pest populations, and microbial activity (Douglas et al. 1980; Stroo et al. 1989; Collins et al. 1990). The goal of effective residue management in conservation tillage systems is to maintain sufficient crop residues at or near the soil surface to minimize erosion, yet not in excessive amounts that impede planting operations or subsequent crop seedling emergence and establishment.

Residue decomposition proceeds at a rate determined by the most limiting environmental, soil, residue, or management factor (Parr and Papendick 1978; Tanaka 1986). Microbial degradation is mainly responsible for crop residue decomposition (Parr and Papendick 1978; Douglas and Rickman 1992), although physical breakdown, removal by wind or water, or use by soil fauna also can significantly affect residue loss (Stott et al. 1990). Environmental factors are temperature and precipitation (Parr and Papendick 1978). Soil factors include available nutrients, pH, and aeration (Smith and Douglas 1968; Tanaka 1986). Residue factors include N content (C/N ratio), chemical composition, size, age, and species or cultivar type (Smith and Douglas 1968, 1971; Parr and Papendick 1978; Douglas et al. 1980; Smith and Peckenpaugh 1986; Collins et al. 1990). Janzen and Kucey (1988) concluded that the rates of decomposition of cereal, oilseed, and pulse crop residues were primarily influenced by their N content. Generally, residues with low N content or high C/N ratios have slower decomposition rates (Parr and Papendick 1978). Management practices affect residue placement or degree of incorporation in soil (Smith and Douglas 1968, 1971; Parr and Papendick 1978). Retention of crop residues on the soil surface decreases the rate of decomposition compared with residues that are partially or completely buried. Brown and Dickey (1970) and Douglas et al. (1980) have shown that surface residue disappears at approximately one-third the rate of buried residue. Residues that are partially or completely buried are subject to greater mechanical disruption and more intimate soil-straw contact than surface residues, which favours microbial decomposition (Douglas et al. 1980).

Degree days (DD) (heat units) recently have been used to quantify crop residue decomposition (Douglas and Rickman 1992), similar to growing DD used to measure the rate of development of annual and perennial crops. Cumulative degree days (CDD) are calculated by summing, for each day, the average daily air temperature minus a base temperature of 0 degrees C. The authors found that the relationship between cereal residue decomposition and CDD was the same at nearly all locations evaluated in the United States. Good agreement was obtained between model predictions and measured results of residue decomposition for wheat residues, using CDD computed from air temperature, and initial N content and placement of the residue. However, the model has not been evaluated in western Canada nor has it been evaluated for predicting residue decomposition of forage legumes and annual crops such as flax and canola. The objective of this paper is to evaluate carbon to nitrogen ratios and other properties of crop residue as a means for predicting decomposition of surface (simulated zero tillage system) and buried (simulated intensive tillage system) spring wheat , barley, canola, and flax straw and alfalfa hay, using data from an experiment conducted in 1991-92 on the long-term chemical fallow site at Melfort, Saskatchewan.

MATERIALS AND METHODS

A crop residue decomposition study was initiated in 1991 on the long-term chemical fallow site (established in 1969) at the Agriculture Canada Research Station at Melfort, Saskatchewan. The soil at the site is a Melfort silty clay (Orthic Black Chernozem) with 9.5% organic matter content and pH 6.0. The long-term experiment is arranged in a randomized complete block design with four replications per treatment. The two year crop rotation consists of spring wheat (Katepwa) alternating with fallow. The tillage treatments for the fallow phase are herbicides only, herbicides in combination with two tillage operations, and tillage alone. The dimensions of individual plots are 4.3 by 30.5 m.

In the 1991 study, unweathered Katepwa wheat straw and alfalfa hay were collected in 1990, immediately after harvest weathered (over winter) wheat straw also was collected in the spring of 1991. In the 1992 study spring wheat, barley, canola and flax straw and alfalfa hay were collected in the fall of 1991. The residues were oven dried at 60 C for 48 h. Twenty-five grams of each residue were placed in nylon mesh (1 mm) bags (25 by 25 cm). The residue bags were placed on the soil surface in the fallow plots of the three tillage treatments (3, 2, and 0 tillage [chemical fallow]) on November 21 in 1991. One-half of those residue bags were buried in the fallow plots at 12-cm depth in June of 1992. Bags were removed from the field at monthly intervals from May 15 (July 3 for the buried bags) to October 23 in 1992.

After removal from the field, residue was sieved (1 mm) to remove loose soil, oven dried, and weighed. The residue was ground to pass through a 1-mm sieve, and a subsample was ashed at 500 C in a muffle furnace over night to determine the soil content within the residue. Residue weights were expressed on an ash-free, dry matter basis. Values for surface and buried residue at each sampling date are means of the four replicate bags per tillage treatment. In this study, residue placement represents two tillage extremes, either surface-placed with no soil incorporation (simulated zero tillage) or completely buried (simulated intensive tillage).

The residue decomposition model is described in detail by Douglas and Rickman (1992). Four equations are used in the model to estimate decomposition of crop residues based on CDD calculated from daily mean air temperature. Each is based on the general equation:

$$Rr = Ir \exp(fN\, fW\, k\, CDD)$$

where Rr = the residue remaining, Ir = the initial residue, fN is an N coefficient based on initial residue N content, fW is a water coefficient based on a combination of residue and field management, and k is a general decomposition coefficient.

RESULTS AND DISCUSSION

The results of the study indicated significant differences in the decomposition of the residues expressed as the proportion (%) of biomass to that of the initial biomass (Figure 1). Both surface and buried residue decomposed in the following order (decreasing rate of decomposition): alfalfa > barley > canola > flax ≥ wheat. However, similar amounts of flax and wheat remained at the end of the 337-day decomposition period (Table 1). The over winter loss of flax was over twice that of wheat. Consequently, the decomposition rates of these two crop residues should be compared in this context. Wheat had the least, and alfalfa the greatest over winter residue loss (6 and 32%, respectively).

Residue decomposed in the field at rates which were similar to those simulated with the Douglas Rickman model (Figure 2). The loss rates reflect differences in overwinter loss and rates of decomposition during the fallow season.

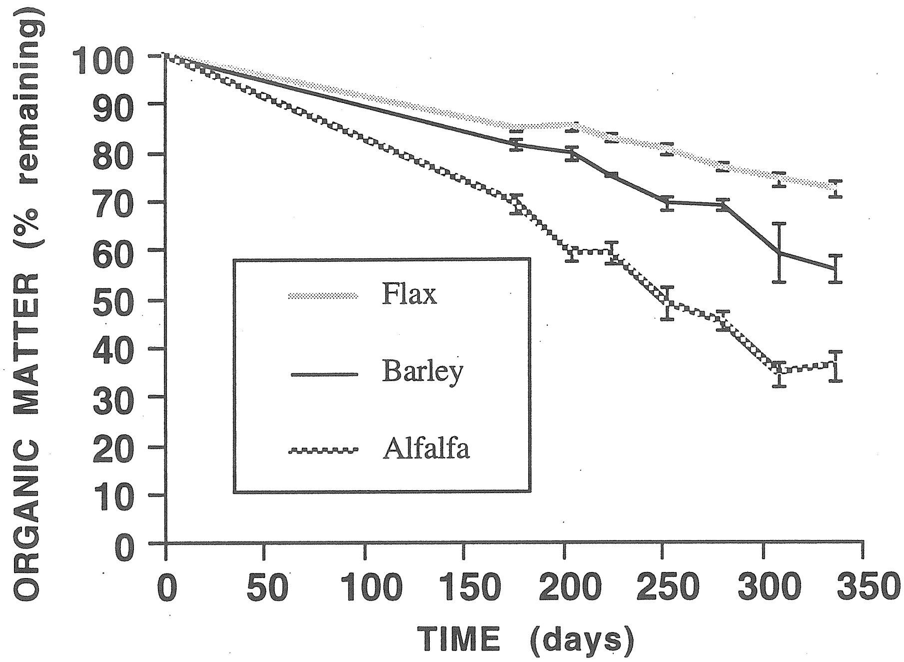

Figure 1. Decomposition of flax, barley and alfalfa at the surface in chemical fallow.

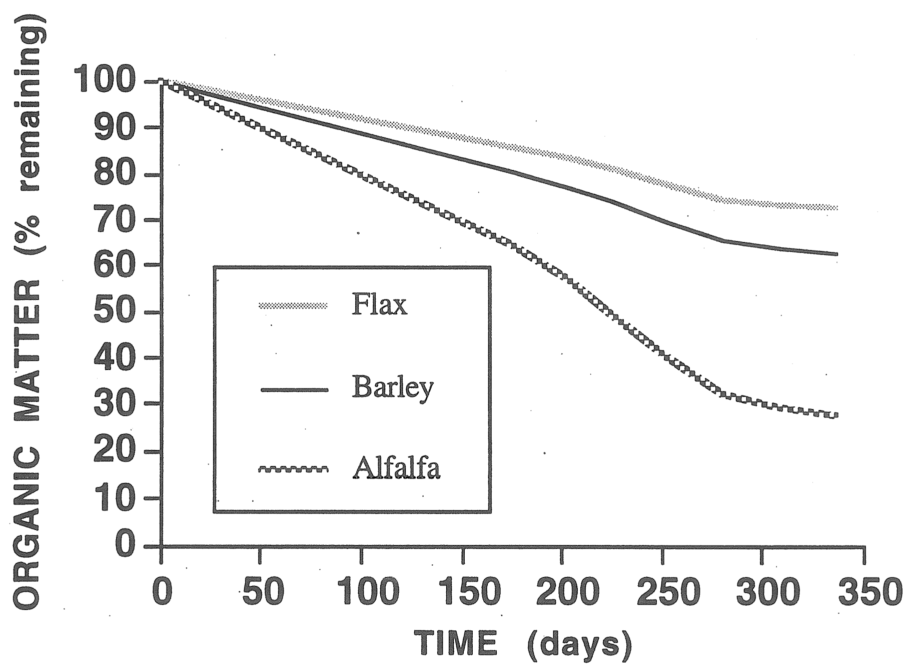

Figure 2. Simulated decomposition of flax, barley and alfalfa residue at the surface.

Table 1. Measured crop residues remaining after 337 days (Nov. 21/1991 to Oct. 23, 1992) at Melfort.

Residue	3 Tillage		2 Tillage		0 Tillage		Over winter loss
	S	B	S	B	S	B	
				%			
Wheat	74	59	77	62	67	54	6
Barley	62	36	65	33	56	26	18
Canola	65	39	67	45	62	42	11
Flax	76	56	73	55	72	50	13
Alfalfa	36	23	36	20	36	11	32

[a]S=surface-placed residue; B=buried residue.

There were significant differences in residue decomposition among the three tillage treatments. Although the tillage effects were more variable during the initial decomposition period, decomposition did not differ between the 3- and 2-tillage treatments towards the end of the experiment and was enhanced under the 0-tillage (chemical fallow) treatment. This is likely due to a more favorable microclimate in the latter treatment. These results are in agreement with findings of the previous year's residue study, which examined the decomposition of unweathered and weathered wheat straw and alfalfa hay. As expected, buried residue decomposed faster than surface residue. Similar to the results in 1991 (Moulin and Beckie 1993), surface residue decomposed at two-thirds the rate of buried residue. In general, both surface and buried wheat and alfalfa residue decomposed at similar rates as determined in the 1991 study. There were few significant tillage by residue, tillage by placement, or residue by placement interactions. In contrast, in 1991 there was a significant residue by placement interaction determined for most of the sampling times.

Significant changes were recorded for C, N, and P expressed as a proportion of initial levels in residue. In the 1991 study involving unweathered and weathered wheat straw and alfalfa hay (Table 2), alfalfa had the highest N content and weathered wheat straw the lowest as expected. Generally, the N content of surface residue was the same as buried residue over the duration of the experiment. Decomposition rates of the three residues corresponded closely to their C/N ratios. Alfalfa, with the lowest C/N ratio, decomposed the fastest whereas weathered wheat residue with the highest ratio decomposed the slowest. The C/N ratios of buried residue were lower than surface residue. Tillage treatment had little effect on the N status or the C/N ratios of all three residues. There usually existed a significant residue by placement interaction at each sampling time.

Table 2. Initial composition of unweathered and weathered wheat straw and alfalfa hay (1991 study).

	Wheat		Alfalfa
	unweathered	weathered	
N(%)	0.41	0.23	2.77
P(%)	0.96	0.63	4.93
C(%)	42.9	44.4	41.7
C/N	105.0	193.0	15.0
Hemicellulose(%)	29.7	20.2	11.4
Cellulose(%)	41.9	52.2	26.4
Lignin(%)	5.9	9.3	6.2

There was no significant tillage effect on hemicellulose, cellulose, or lignin content of the three types of residue. At the end of the experiment, alfalfa which decomposed the fastest, had the lowest hemicellulose and cellulose content (more readily decomposable fractions), and the highest % lignin (least decomposable fraction) compared with wheat. Similarly, surface residue, which decomposed less rapidly than buried residue, had higher percent hemicellulose and cellulose and lower percent lignin compared with the latter residue.

In the 1992 study, alfalfa had the highest percentage N, followed by barley = canola > wheat ≥ flax (Table 3). Similarly, the C/N ratios of the five residues were (from lowest to highest): alfalfa ≤ barley ≤ canola < wheat ≤ flax. This generally corresponds to their rate of decomposition over the period from the first to last sampling time. With the exception of alfalfa, the percent N of surface and buried residue tended to increased over time in both years. For alfalfa hay with an inherently high N content, N concentrations remained constant or declined over time. The N concentration dynamics were reflected in the C/N ratios, which tended to decline over time (barley, canola, wheat, and flax) or stay constant (alfalfa). These trends likely reflect the influence of C/N ratios of the residues on the processes of mineralization and immobilization. Residues with high C/N ratios would require soil N (immobilization of soil N) for decomposition to proceed.

Table 3. Initial composition of residue used in the 1992 study.

	Wheat	Barley	Canola	Flax	Alfalfa
N(%)	0.53	0.64	1.06	0.37	2.22
P(%)	1.64	5.01	1.77	0.89	4.68
C(%)	45.1	43.0	42.7	47.3	44.3
C/N	85.0	67.0	40.0	128.0	20.0
Hemicellulose(%)	24.3	29.0	12.2	15.9	10.1
Cellulose (%)	50.9	41.2	48.0	52.8	27.8
Lignin(%)	4.8	4.7	7.3	13.2	6.1

As in 1991, there was no tillage effect on the composition of the residues, including hemicellulose, cellulose, or lignin, from the first to last sampling time.

As well, there were few significant interactions between residue, placement, or tillage. The cellulose content, like N concentration or C/N ratio, was generally a good predictor of decomposition rate: alfalfa < barley < canola = wheat ≤ flax. Hemicellulose concentration was less reliable as a predictor of decomposition: alfalfa = canola ≤ barley = flax ≤ wheat; lignin concentration was least reliable: wheat ≤ barley < alfalfa = canola < flax. As in the 1991 study, surface residue had a higher concentration of hemicellulose and cellulose and lower lignin concentration compared with buried residue. As well, in both years the decline in the hemicellulose and cellulose concentration and increase in percent lignin over time was greatest for buried than surface residue, reflecting their relative rates of decomposition.

CONCLUSIONS

Decomposition rates of crop residues of spring wheat, barley, alfalfa, and flax are closely related to the nitrogen content of the straw or hay. The Douglas/Rickman model which uses the nitrogen content of crop residues to predict decomposition, should provide reasonable estimates of changes of crop residue during the fallow season. More research is required to predict loss of crop residue over winter and in crop canopies.

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